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(54) Stoppers for use in molten metal handling

(57) A stopper for use in the control of melt flow in molten metal handling operations comprises a monoblock refractory body 1 having a longitudinal throughbore 2 with an upper portion adapted to receive a support means including a metal rod which also provides a gas supply conduit 7, the upper portion having a threaded form 4 to engage with a correspondingly threaded form on the metal conduit rod 7 so as to bring the metallic tip 6 of the conduit rod 7 into contact with a ceramic seating surface 5 within the stopper body forming a gas tight compression seal by tightening of the engaged threaded forms. Various compressible metal tip forms are disclosed (Figs. 3-6). In a further embodiment (Fig. 7), the refractory material provides a seat which is compressed by a relatively hard metallic insert tip of the conduit rod. A locking arrangement for locking the rod to the body is also disclosed (Fig. 8).

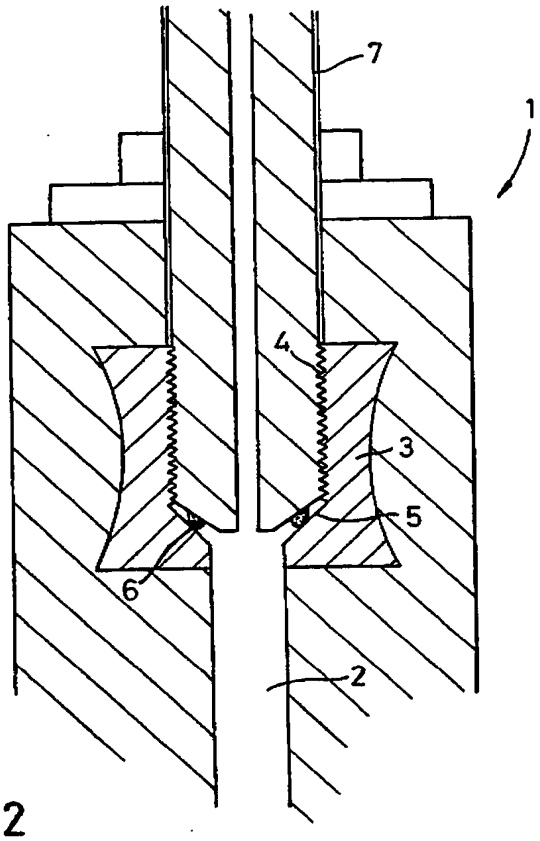
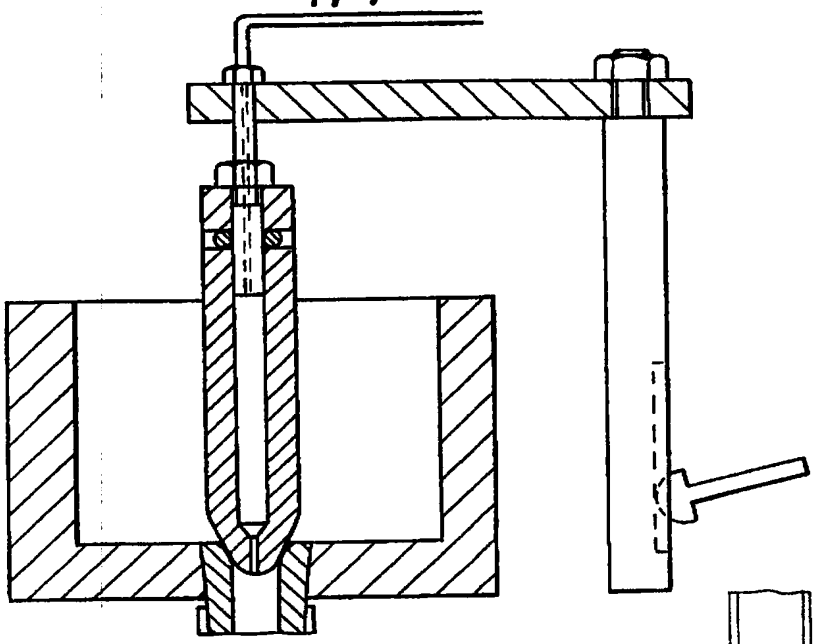


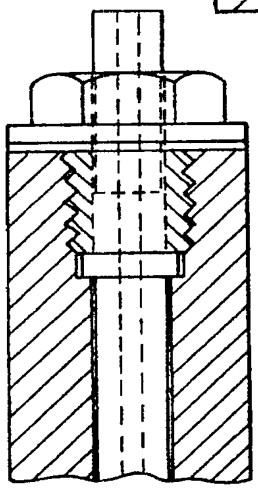
Fig. 2

GB 2 247 637 A

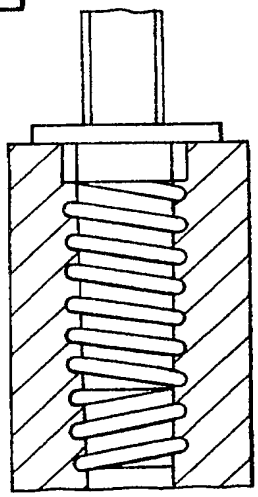
At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.



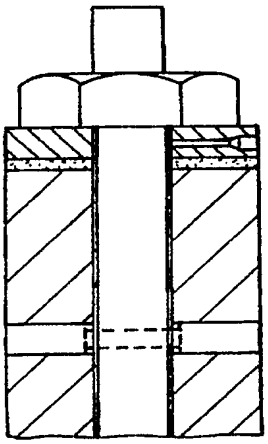
ALTERNATIVE FIXING SYSTEMS



CERAMIC INSERT

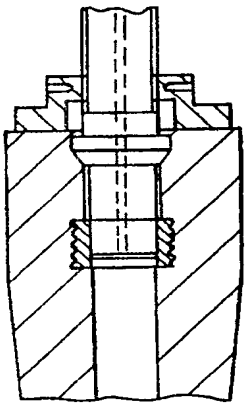


STEEL THREAD



CROSS PIN

Fig. 1



INTERNAL CO-PRESSED METAL INSERT

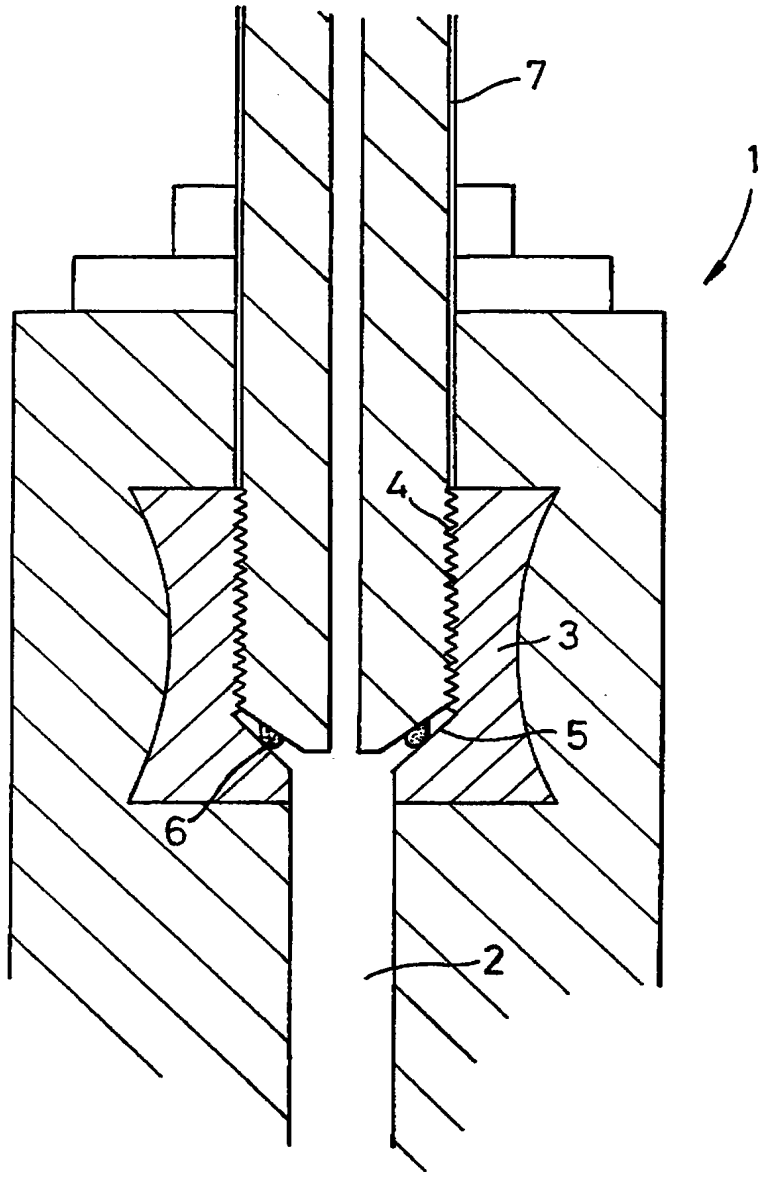


Fig. 2

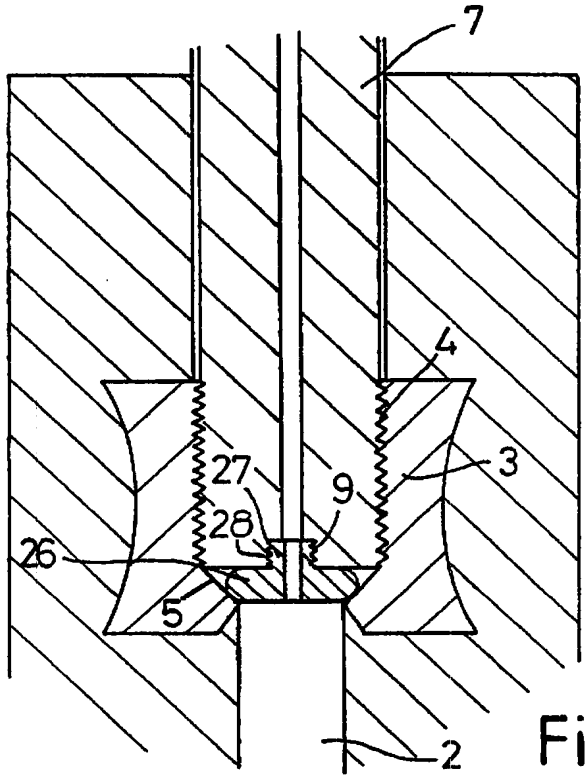


Fig. 3

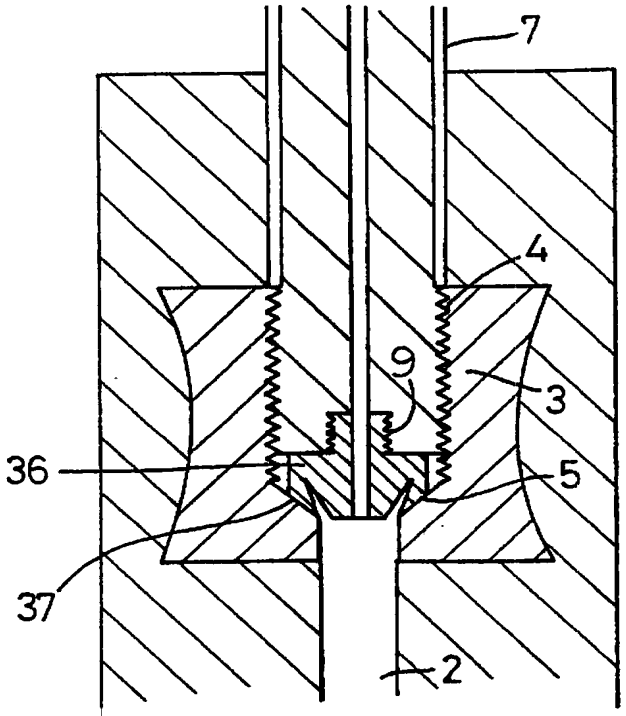


Fig. 4

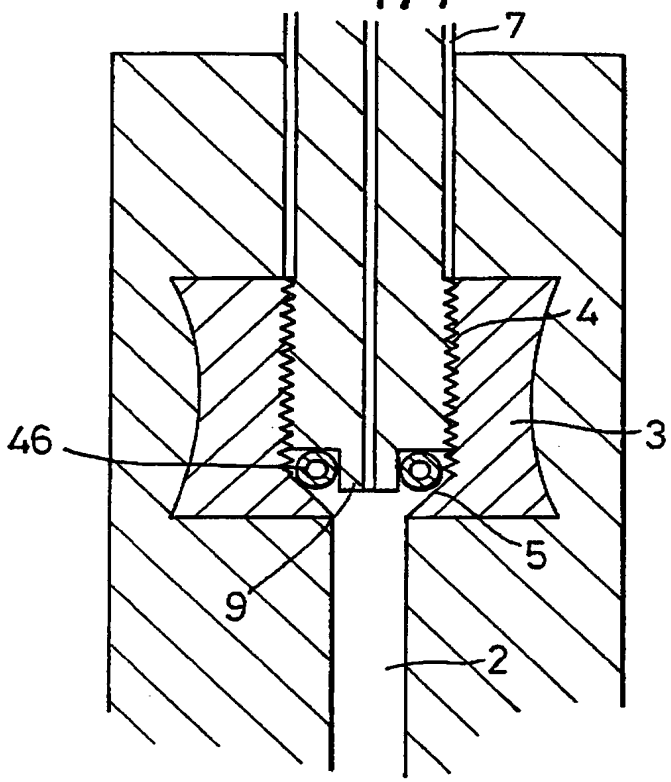


Fig. 5

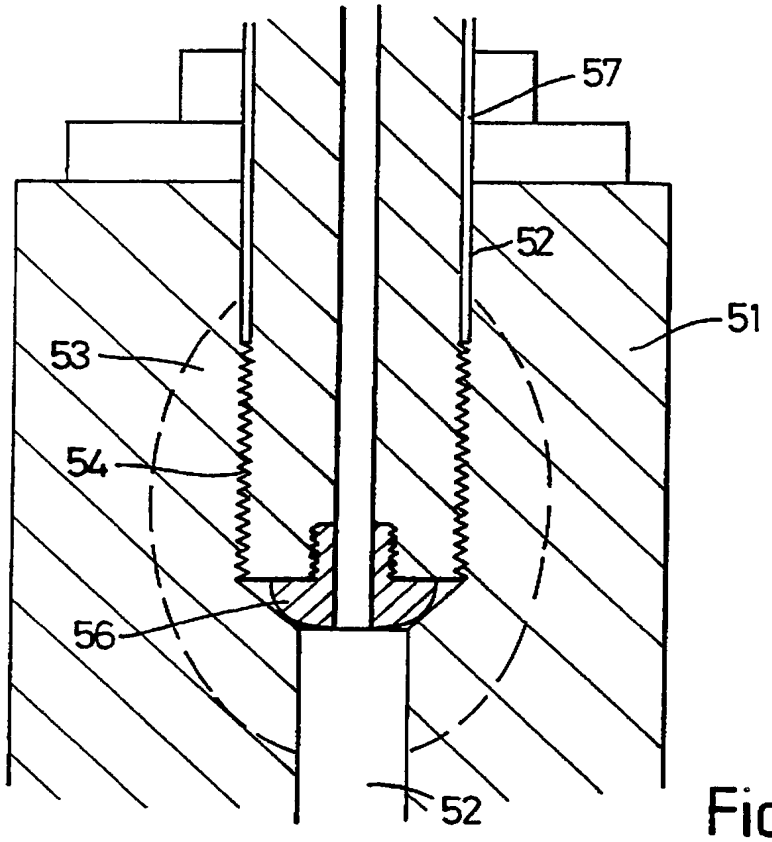


Fig. 6

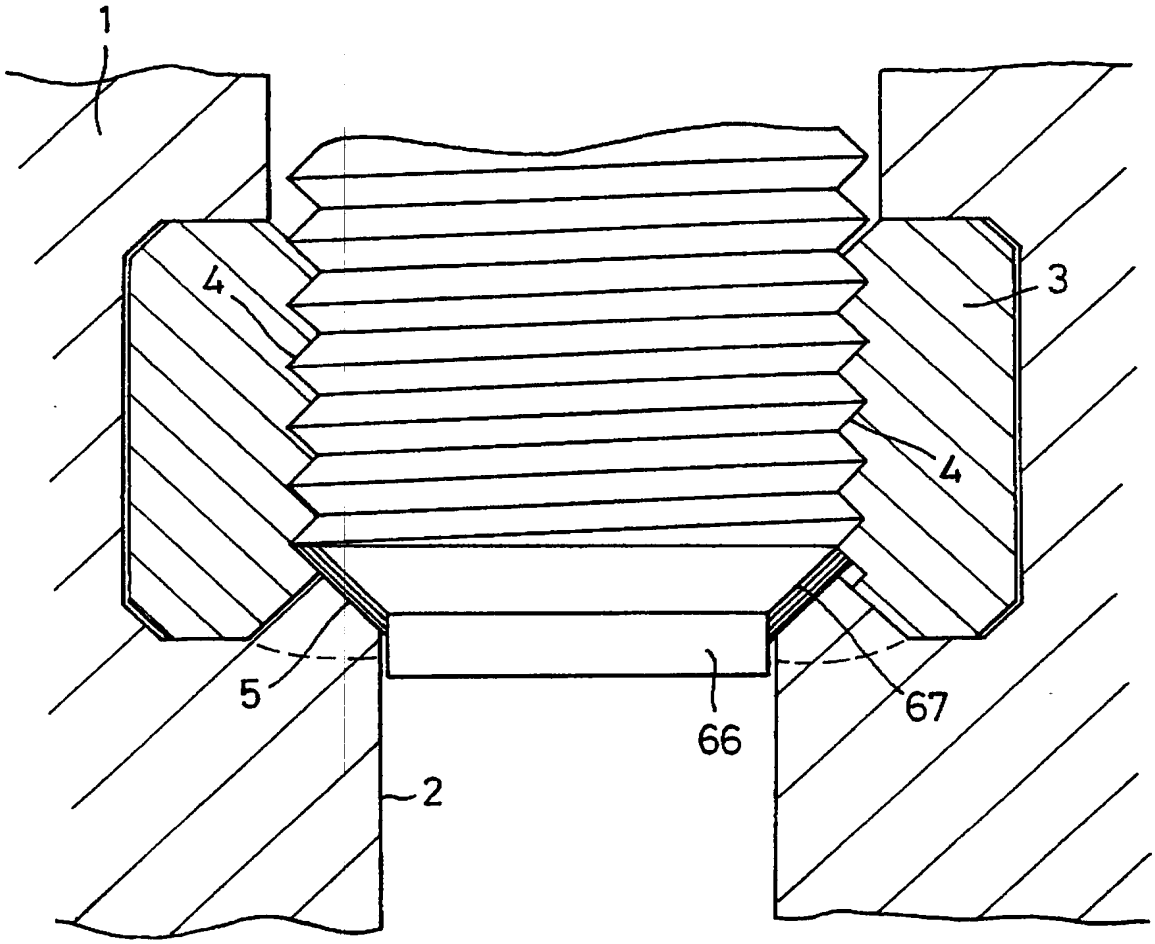


Fig. 7

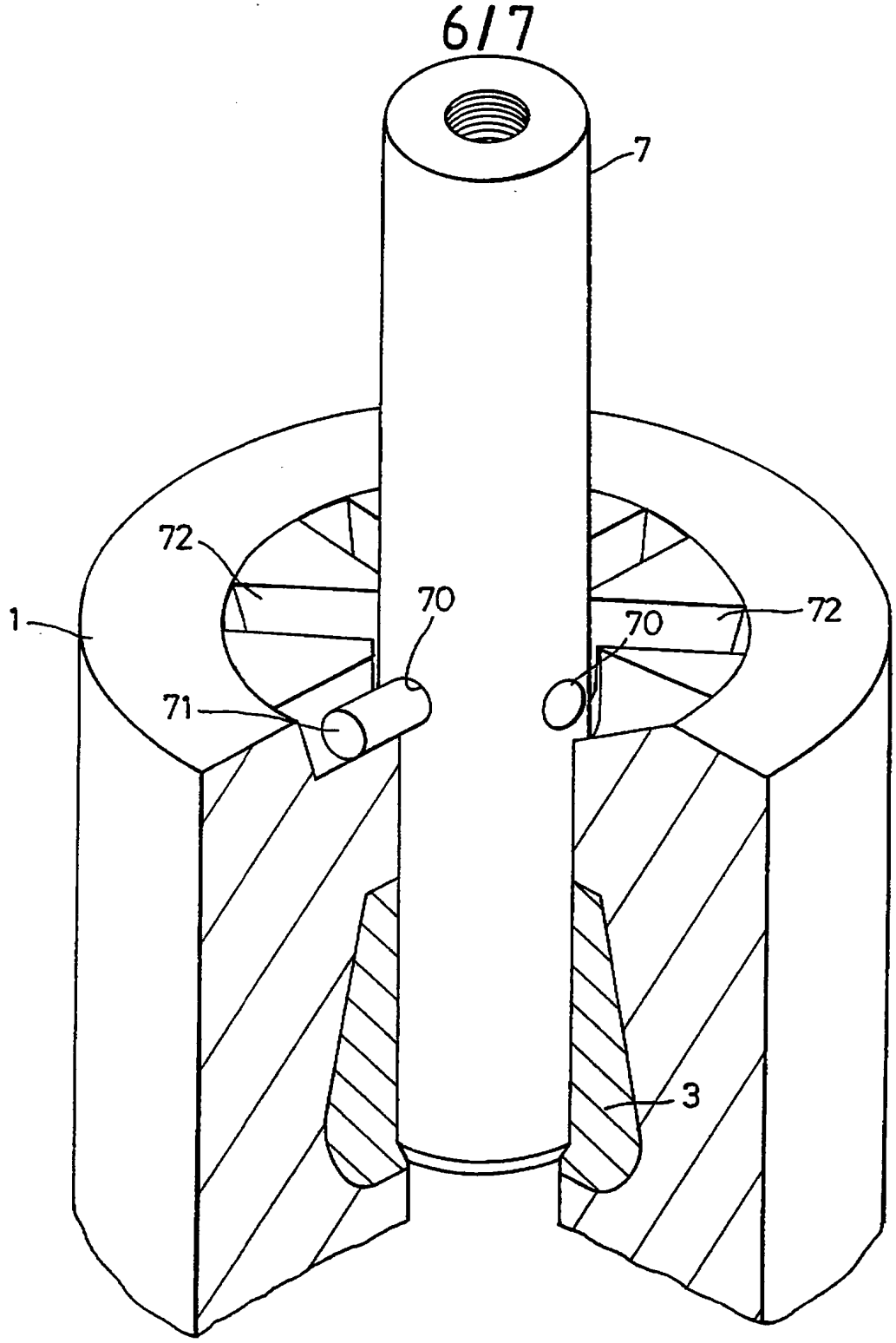


Fig. 8

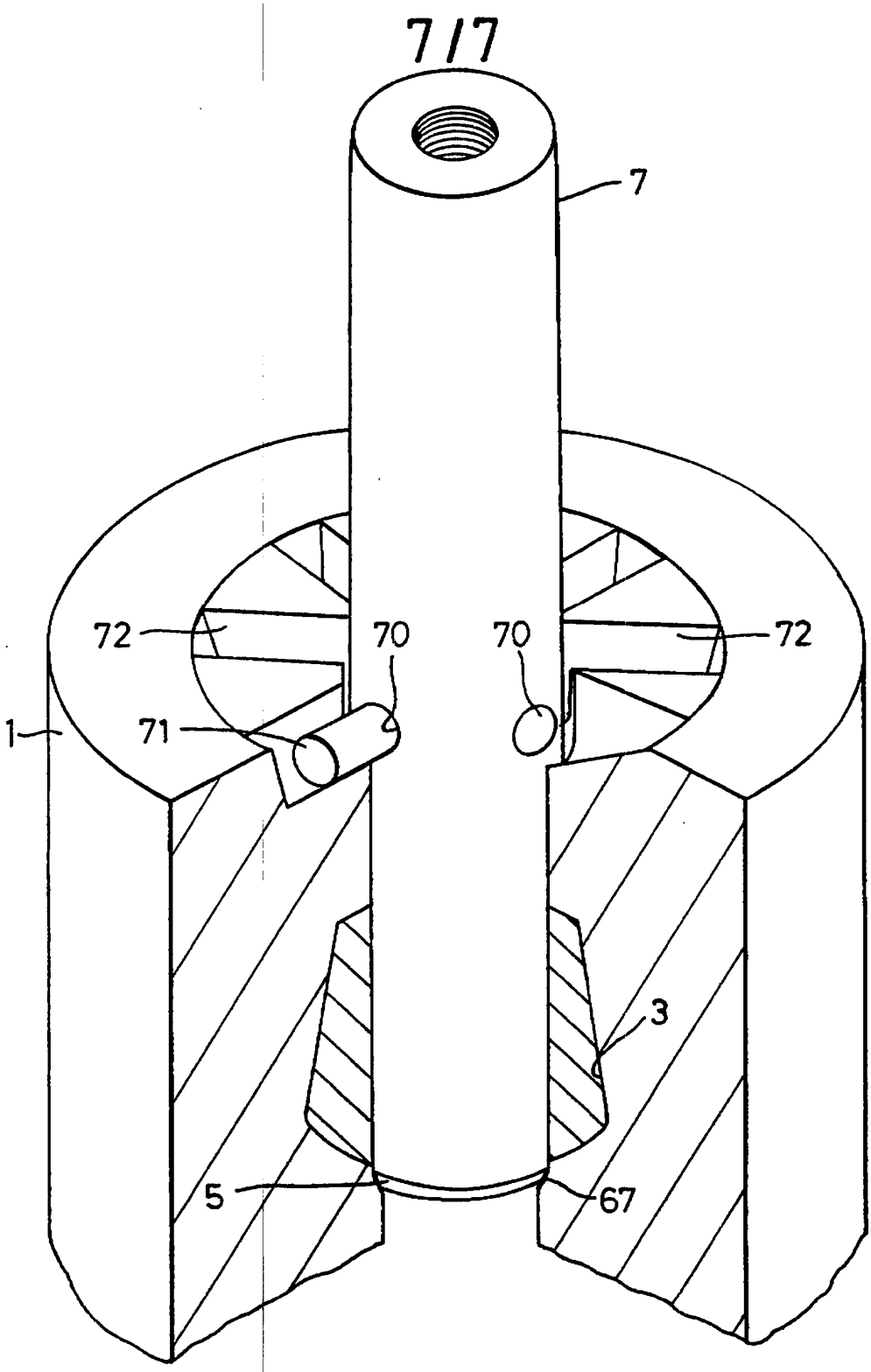


Fig. 9

STOPPERS FOR USE IN MOLTEN METAL HANDLING

This invention relates to a stopper used in the control of flow of molten material from a vessel through a submerged outlet, as for example in the pouring of molten steel from a tundish.

In known processes for the continuous casting of steel, it is common to employ a one-piece refractory stopper rod for controlling the flow of molten metal through a nozzle orifice from the tundish into a water-cooled mould. A lifting mechanism is used to vertically lift the stopper rod to adjust and control the volume of the molten metal flowing through the nozzle. Although the principal of operation of such a stopper rod is quite simple, in practice, such a stopper rod has to operate under harsh environmental conditions such as being submerged in the molten metal for long periods of time and must be able to withstand the high thermal shocks encountered in the pouring processes.

Furthermore, it is now common practice to provide a stopper rod with means for injecting an inert gas through the stopper rod into the nozzle to prevent fouling of the nozzle by deposition of alumina or other contaminants e.g. non-metallic oxides. Normally, this is accomplished using a stopper with a through-bore formed longitudinally within the stopper from one end to the other, which may converge at the nose to provide a narrow gas injection nozzle or vent through a porous region in the nose. This type of stopper, referred to hereinafter as a "gas-ducted stopper", has a gas supply line fastened to the upper end of the through-bore which then acts as a gas duct to convey inert gas to the stopper nose. However, due to the relatively complex mountings and fittings attached to the upper end of such a stopper, there are a large number of joints through which the inert gas can escape. In view of the temperatures of operation all the joints are dry-sealed, i.e. close fitting ceramic/metal joints possibly including special gaskets without sealing compounds. However, these joints are never perfect and a certain amount of gas loss is inevitable.

Inert gas is an expensive material and losses through joints in the system demand use of large volumes of gas to ensure sufficient gas is delivered onto the throat of the

nozzle to provide a beneficial effect which increases costs to a level which is no longer acceptable to the industry.

The use of high gas volumes to overcome gas losses also introduces a potential variability in mould turbulence effects which can adversely affect cast metal quality.

Further study of this system has revealed that in use molten metal pouring through a submerged entry nozzle creates a venturi effect in the throat of the nozzle which has been observed to cause a vacuum of down to about 15 torr in the through-bore of the stopper. This vacuum draws in air from the surroundings through any imperfections in the joints of the stopper assembly and argon supply system which defeats the purpose of introducing argon in the first instance by introducing air into the inert gas stream and thus contaminating the melt.

Applicant's earlier European Patent No 179837 discloses improvements in gas-ducted stoppers.

A common method of attaching a stopper rod to a lifting device and inert gas supply comprises inserting a ceramic, threaded insert onto a flanged steel rod of the lifting device. The ceramic insert is threadably secured within a threaded bore which is formed by isostatic pressing at the top of the stopper rod.

This attachment system has a number of major disadvantages not least of which is that, as mentioned above, it has proved very difficult in the past to provide a gas tight seal between the stopper rod and the insert.

It has been further noticed that in other known stoppers which have a metal threaded insert isostatically pressed into the body of the stopper, the insert having a threaded portion through which the stopper rod extends, thermal expansion between the metal rod and the metal insert means that greater expansion of the metal tends to lift the sealing surface of the rod away from the corresponding sealing surface of the ceramic body and thus opens the intended gas-tight seal.

The present invention aims to provide a stopper which overcomes or at least mitigates the above mentioned disadvantages.

According to the present invention there is provided a stopper comprising a monoblock refractory body having a longitudinal throughbore with an upper portion adapted to receive a support means including a metal rod which also provides a gas supply conduit, the upper portion having a threaded form to engage with a correspondingly threaded form on the metal conduit rod so as to bring the metallic tip of the conduit rod into contact with a ceramic seating surface within the stopper body forming a gas tight compression seal by tightening of the engaged threaded forms.

In one form of the invention, the ceramic seating surface is relatively soft and may be compressed against the harder tip of the stopper in order to form the seal.

Alternatively, the metallic tip may be formed of a relatively soft metal and the ceramics seating surface may be formed of a relatively hard ceramics wherein the soft tip of the conduit rod is compressed against the ceramic seating surface.

Each of these arrangements has the advantage that the sealing surface between the ceramic and the tip of the metallic conduit is spaced from the enmeshed threaded portion of the assembly by a length of the metal conduit rod so that the greater expansion of the metal compared to the ceramic at the elevated temperatures experienced in service in for example the process of continuous casting of steel from a tundish acts to force the seal tip into a tighter engagement with the ceramic seating surface.

The soft metal sealing tip may be in the form of an annular ring of the desired softness, e.g. copper alloy applied by conventional brazing or spray deposition techniques, or alternatively a replaceable sealing tip of suitable soft material may be attached, preferably by threaded engagement with the rod e.g. into a suitable recess in the end of the metal conduit rod, with the advantage of this tip being readily replaced allowing reuse of the system in the event of accidental tip damage or wear.

Preferably the upper portion of the through bore of the stopper for receiving the support conduit rod is formed by a zone of hard wear-resistant ceramic material co-pressed into

the body to produce both the thread form for engagement with the thread of the metal support conduit and the sealing surface to receive the soft seal tip of the metal conduit rod.

This zone of hard wear resistant material may be a preformed refractory artifact made from, for example, silicon nitride-bonded silicon carbide material, known as an engineering ceramic for its excellent mechanical properties. This artifact is placed in the mould and surrounded by particulate refractory materials of composition established as suitable for the manufacture of a monoblock stopper, for example carbon bonded alumina graphite.

The stopper shape is then formed by isostatic pressing or other suitable forming method resulting in a composite body of high integrity which is then subject to the normal curing and firing processes.

Alternatively, this zone of hard wear resistant material may be formed by selecting compatible refractory materials and using specialist filling techniques known *per se* to provide regions or zones of two different materials in the required position within the monoblock stopper. For example, the main body of the stopper may comprise carbo-ceramic bonded alumina graphite, the hard thread formed artifact and sealing surface comprising carbo-ceramic bonded zirconia mullite.

Once the two particulate materials are positioned within the mould they are subjected to isostatic press forming to produce a composite monobloc body having the required combination of properties wherein the artifact or insert is wholly integrated. The composite body is then subject to normal curing and firing processes.

In one form of the invention, the metallic sealing tip on the conduit rod is designed to be softer than the hard ceramic seating surface and also to expand at the operational temperatures of for example a continuous steel casting process to increase the joint integrity.

Furthermore, the sealing tip may be designed with special contours to deform in a predetermined manner by the compressive force generated between the meshing thread forms

and the hard ceramic sealing surface within the through bore so as to increase the integrity of the sealing effect.

The present invention also provides a locking means for inhibiting disengagement of a metal conduit rod from a stopper body comprising corresponding means on the rod and the stopper for receiving a locking member thereby holding the conduit rod in fixed relation to the stopper.

In order that the present invention may be more easily understood, and so that further features thereof may be more appreciated, reference will now be made to the accompanying drawings, in which:

FIGURE 1 illustrates typical arrangements available in the prior art;

FIGURE 2 is a cross-sectional view of a stopper according to one aspect of the present invention;

FIGURE 3 is a cross-sectional view of a stopper according to a second aspect of the present invention;

FIGURE 4 is a cross-sectional view of a stopper according to a third aspect of the present invention,

FIGURE 5 is a cross-sectional view of a stopper according to a further aspect of the present invention,

FIGURE 6 is a cross-sectional view of a stopper according to a still further aspect of the present invention,

FIGURE 7 is a cross-sectional view of a stopper according to a still further aspect of the present invention;

FIGURE 8 is a part-sectional perspective view of a locking means for a stopper according to the present invention; and

FIGURE 9 is a part-sectional perspective view of a locking means for a stopper as shown in Fig. 7.

Example 1

A stopper for use in the control of melt flow in molten metal handling operations (referring to Figure 2) comprises

a refractory body 1 of the monobloc type having a generally cylindrical shape and having upper and lower ends and an axial bore 2 extending between the upper and lower ends. A hard, high strength preformed ceramic insert 3 is isostatically pressed into the stopper, the insert 3 providing a threaded bore 4 through which the stopper rod of a typical mounting assembly for the stopper passes.

The ceramic insert 3 has a tapered portion 5 of reduced diameter below the threaded portion 4 of the insert. This portion of reduced diameter 5 provides a sealing surface for a sealing tip 6 carried by the rod.

The stopper rod comprises a cylindrical gas supply conduit 7 having a lower threaded surface which corresponds to the thread 4 on the ceramic insert 3 and allows the conduit 7 to be releasably engaged with the insert 3 within the stopper.

The sealing tip 6 comprises a generally annular member of soft metal e.g. brazed copper whose profile matches to the hard tapered seating portion 5 of the ceramic insert 3 and thus provides a reliable seal within the stopper.

As the sealing surface between the stopper and the gas conduit 7 is entirely below the threaded portion 4 of the ceramic insert 3, any expansile differences between the stopper and the insert 3 act to force the sealing tip 6 and insert 3 into engagement rather that lifting the sealing tip 6 away from the sealing surface 5 of the ceramic insert 3 as was the case with previous stoppers used in this process.

Example 2

A stopper for use in the control of melt flow in molten metal handling operations (referring to Figure 3) comprises a refractory body 1 of the monoblock type having a generally cylindrical shape and having upper and lower ends and an axial bore 2 extending between the upper and lower ends. A hard, high strength preformed ceramic insert 3 is isostatically pressed into the stopper, the insert 3 providing a threaded bore 4 through which the stopper rod of a typical mounting assembly for the stopper passes.

The ceramic insert 3 has a tapered portion 5 of reduced diameter below the threaded portion 4 of the insert 3. This

portion of reduced diameter provides a sealing surface 5 for a sealing tip 26 carried by the rod.

The stopper rod comprises a cylindrical gas supply conduit 7 having a lower threaded surface which corresponds to the thread 4 on the ceramic insert 3 and allows the conduit 7 to be releasably engaged with the insert 3 within the stopper. The lower end of the conduit 7 has an axial threaded aperture 9 through which an inert gas may be applied to the tip 26 of the stopper rod for the purposes, and in a manner generally known *per se*.

The sealing tip 26 comprises a hemispherical, member which may be partially or fully deformable. The tip 26 has an upstanding projection 27 which is provided with an external thread 28 for engagement with the thread 9 at the end of the stopper rod. The hemispherical sealing tip 26 communicates with the hard tapered portion 5 of the ceramic insert 3 as the conduit 7 is threaded into the stopper to provide a seal between the ceramic insert 3 and the conduit 7.

Example 3

A stopper for use in the control of melt flow in molten metal handling operations (referring to Figure 4) comprises a refractory body 1 of the monoblock type having a generally cylindrical shape and having upper and lower ends and an axial bore 2 extending between the upper and lower ends. A hard, high strength preformed ceramic insert 3 is isostatically pressed into the stopper, the insert 3 providing a threaded bore 4 through which the stopper rod of a typical mounting assembly for the stopper passes.

The ceramic insert 3 has a tapered portion 5 of reduced diameter below the threaded portion 4 of the insert 3. This portion of reduced diameter 5 provides a hard sealing surface for a seal tip 36 carried by the rod.

The stopper rod comprises a cylindrical gas supply conduit 7 having a lower threaded portion which corresponds to the thread 4 on the ceramic insert 3 and allows the conduit 7 to be releasably engaged with the insert 3 within the stopper. The lower end of the conduit 7 has an axial threaded aperture 9 through which an inert gas may be

applied to the tip 36 of the stopper rod for the purposes, and in a manner generally known *per se*.

The sealing tip 36 comprises a deformable member which is releasably received in the end of the conduit 7 in the same way as the examples discussed above. The tip 36 has a tapered surface 37 of mismatching angle to the hard tapered sealing surface 5 of the ceramic insert 3 and a corrugated form which allows the sealing surface 37 to deform against the hard ceramic insert 3 when the conduit 7 is tightened into the insert thread 4 and produces the required seal between the insert 3 and the conduit 7.

Example 4

A stopper for use in the control of melt flow in molten metal handling operations (referring to Figure 5) comprises a refractory body 1 of the monoblock type having a generally cylindrical shape and having upper and lower ends and an axial bore 2 extending between the upper and lower ends. A hard, high strength preformed ceramic insert 3 is isostatically pressed into the stopper, the insert providing a threaded bore through which the stopper rod of a typical mounting assembly for the stopper passes.

The ceramic insert 3 has a tapered portion 5 of reduced diameter below the threaded portion 4 of the insert 3. This portion of reduced diameter 5 provides a seating surface for a sealing means 46 carried by the rod tip.

The stopper rod comprises a cylindrical gas supply conduit 7 having a lower portion threaded portion which corresponds to the thread 4 on the ceramic insert 3 and allows the conduit 7 to be releasably engaged with the insert 3 within the stopper. The lower end of the conduit 7 has an axial projection 9 through which the inert gas is introduced to the tip of the stopper for the purposes, and in a manner generally known *per se*.

The sealing means on the tip comprises a deformable O-ring 46 or washer which is forced over the end of the axial projection 9. As the conduit 7 is threaded into the ceramic insert 3 the O-ring or washer 46 is compressed between the hard tapered seating surface 5 of the ceramic insert 3 and

the conduit 7 and provides the required seal for the stopper.

Example 5

A stopper for use in the control of melt flow in molten metal handling operations (referring to Figure 6) comprises a refractory body 51 of the monoblock type having a generally cylindrical shape and having upper and lower ends and an axial bore 52 extending between the upper and lower ends through which the stopper rod of a typical mounting assembly for the stopper passes.

The upper portion of the bore 52 of the stopper is formed by a zone of hard wear-resistant refractory material 53 which is co-pressed into the stopper body to produce a threaded surface 54 for engagement with a threaded portion of the stopper rod which comprises a cylindrical gas supply conduit 57.

The zoned material 53 is preferably formed by selecting appropriate refractory materials and bonding agents e.g. carbon ceramically bonded zirconia mullite, packing the same into the mould and isostatically pressing to form a monoblock refractory body 51 in which there is no obvious artifact or insert.

The sealing tip 56 illustrated in Figure 5 is similar in construction to the one described with reference to Figure 2, however, it is to be understood that any of the sealing tips described above could be used with the stopper of Figure 5.

Example 6

In a further alternative arrangement, a stopper for use in the control of melt flow in molten metal handling operations (referring to Figure 7) comprises a refractory body 1 of the monoblock type having a generally cylindrical shape and having upper and lower ends and an axial bore 2 extending between the upper and lower ends. A hard, high strength preformed ceramic insert 3 is isostatically pressed into the stopper, the insert providing a threaded bore through which the stopper rod of a typical mounting assembly for the stopper passes.

The refractory body 1 provides a relatively soft tapered portion 5 of reduced diameter below the threaded portion 4 of the insert 3. This portion of reduced diameter 5 provides a sealing surface for a sealing tip 66 carried by the rod.

The stopper rod comprises a cylindrical gas supply conduit 7 having a lower threaded portion which corresponds to the thread 4 on the ceramic insert 3 and allows the conduit 7 to be releasably engaged with the insert 3 within the stopper.

The sealing tip 66 comprises a relatively hard metallic member which is releasably received in the end of the conduit 7 in an appropriate manner. The tip 66 has a tapered surface 67 of mismatching angle to the tapered sealing surface 5 of the refractory body 1 and compresses the softer ceramics seating surface when the conduit 7 is tightened into the insert thread 4 thereby producing the required seal between the refractory body 1 and the conduit 7.

The present invention also provides a means for preventing disengagement of the conduit 7 from the refractory body 1 during use of the stopper. Figures 8 and 9 show a part-sectional perspective view of the upper portion of the conduit 7 and refractory body 1. The outer surface of the conduit 7 is provided with a plurality of equidistant indentations 70 for receiving and retaining a locking pin 71. The locking pin 71 is inserted into one of the indentations 70 through one of a plurality of slots 72 in the upper portion of the refractory body 1. The upper portion of the stopper may then be covered with concrete.

Experiments have shown that for a typical rod diameter of say 39 mm, the optimum arrangement is achieved when 4 indentations are provided in the conduit 7 and 11 slots are provided in the refractory body 1. Thus for any relative angular position of the conduit with respect to the refractory body, one of the indentations 70 is sufficiently aligned with a slot 72 to allow the locking pin 71 to be inserted into the indentation to resist disengagement of the conduit from the refractory body. It is a simple matter to

apply a settable compound e.g. refractory cement to ensure permanent fixing of the pin to prevent rotation of the rod within the stopper body. The following table gives data relating to the locking mechanism for various rod diameters.

Table I

Screwed rod end diameter	No. of slots on stopper	angle (°) between slots	radial movement (mm)	angular movement (°)
30 mm	9	40	10.5	10
39 mm	11	32.7	11.2	8.1
52 mm	15	24	10.9	6

The above data is calculated for an 8 mm diameter pin locating in a 10 mm diameter wide slot. Providing the angular movement is as stated for each rod end diameter, a lockable position is achieved at any final gas tight position.

The results of testing the gas-tightness of the seal of this invention show an impressive improvement at operating temperatures typically encountered in steel casting, as is evident from Table II below.

Testing involved measuring the back-pressure of gas fed into the conduit (cold and hot, simulating conditions between start up using a new stopper and operating at up to 1090°C) which may be correlated with the amount of leakage of gas through the system (seal).

Table II

Pressure (cold)	Volume of leakage	Pressure (hot)	Volume of leakage	Final Temperature
0.3 bar	5 l/min	0.35 bar	2 l/min	1050°C
0.3 bar	5 l/min	0.45 bar	0 l/min	1050°C
0.4 bar	1 l/min	0.45 bar	0 l/min	1090°C
0.4 bar	1 l/min	0.45 bar	0 l/min	1090°C

The first two tests involved deformable metal rod tips with a rigid non-compressible artifact co-pressed into the

stopper, i.e. a hard engineering ceramic sealing surface according to Example 1. The next two tests involved use of a relatively hard metal tip under compression against a softer carbon bonded alumina graphite in the seal area e.g. as in Example 6.

Thus it can be seen that with a stopper of this invention of the types described above, many of the disadvantages associated with known stoppers can be overcome or at least mitigated.

CLAIMS

1. A stopper for use in the control of melt flow in molten metal handling operations comprising a monoblock refractory body having a longitudinal throughbore with an upper portion adapted to receive a support means including a metal rod which also provides a gas supply conduit, the upper portion having a threaded form to engage with a correspondingly threaded form on the metal conduit rod so as to bring the metallic tip of the conduit rod into contact with a ceramic seating surface within the stopper body forming a gas tight compression seal by tightening of the engaged threaded forms.

2. A stopper according to claim 1 wherein the ceramic seating surface is of a material compressible by the tip of the stopper.

3. A stopper rod according to claim 1 wherein the metallic tip is deformable by compression against the ceramics seating surface.

4. A stopper according to claim 3 wherein the metal sealing tip is in the form of an annular ring of copper alloy.

5 A stopper according to claim 3 wherein the metal sealing tip is a replaceable tip threaded into a recess in the end of the metal conduit rod.

6. A stopper according to any one of claims 3-5 wherein the upper portion of the through bore of the stopper for receiving the support conduit rod is formed by a zone of wear-resistant refractory ceramic material co-pressed into the body to provide both the thread form for engagement with the thread of the metal support conduit and the sealing surface against which the sealing tip of the metal conduit rod is compressed to form the seal.

7. A stopper according to claim 6 wherein the zone of wear resistant material is a preformed refractory artifact made from a silicon nitride-bonded silicon carbide material.

8. A stopper according to claim 6 wherein the main body of the stopper comprises co-pressed particulate materials comprising carbo-ceramic bonded alumina graphite with an integral zone of carbo-ceramic bonded zirconia mullite.

9. A stopper according to any one of claims 3-8 wherein the sealing tip is so shaped as to have a deformable peripheral contour.

10. A stopper according to claim 9 wherein the sealing tip has a corrugated form.

11. A stopper substantially as hereinbefore described with reference to and as shown in Figs. 2-7 of the accompanying drawings.

12. A locking means for preventing disengagement of a metal conduit rod from a stopper body comprising corresponding recesses on the rod and the stopper for receiving an interference fit locking member thereby holding the conduit rod in fixed relation to the stopper.

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